

AD-753 489

ELECTRIC CONDUCTIVITY OF A HIGH-DENSITY  
XENON PLASMA

S. I. Andreev, et al

Foreign Technology Division  
Wright-Patterson Air Force Base, Ohio

17 November 1972

DISTRIBUTED BY:

**NTIS**

National Technical Information Service  
U. S. DEPARTMENT OF COMMERCE  
5285 Port Royal Road, Springfield Va. 22151

AD753489

FTD-HT-23-1202-72

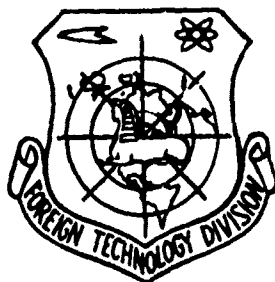
## FOREIGN TECHNOLOGY DIVISION



ELECTRIC CONDUCTIVITY OF A  
HIGH-DENSITY XENON PLASMA

by

S. I. Andreyev and V. Ye. Gavrilov



Approved for public release;  
distribution unlimited.

Reproduced by  
NATIONAL TECHNICAL  
INFORMATION SERVICE  
U S Department of Commerce  
Springfield VA 22151

10

UNCLASSIFIED  
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Foreign Technology Division Air Force Systems Command U. S. Air Force		2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	
		2b. GROUP	
3. REPORT TITLE  ELECTRIC CONDUCTIVITY OF A HIGH-DENSITY XENON PLASMA			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Translation			
5. AUTHOR(S) (First name, middle initial, last name)  Andreyev, S.I.; Gavrilov, V.Ye.			
6. REPORT DATE 1970		7a. TOTAL NO. OF PAGES 10	7b. NO. OF REFS 6
8a. CONTRACT OR GRANT NO.  b. PROJECT NO. 4152/02  c.  d.		8b. ORIGINATOR'S REPORT NUMBER(S) FTD-HT-23-1202-72  8c. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
10. DISTRIBUTION STATEMENT  Approved for public release; distribution unlimited.			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Foreign Technology Division Wright-Patterson AFB, Ohio	
13. ABSTRACT  The temp. dependence of the sp. cond. of a xenon plasma was studied for high concns. of the charged particles when the notion for Debye screening was not applicable. For discharge tube diams. of 7.4-15.5 mm and under pressures of 200-600 T or R, similar dependences were found: with increasing temp. from 10,000 to 20,000°K, the sp. cond. rose from 60 to 190 omega-anion(1) cm-anion(1). An attempt was made to obtain theoretically the exptl. found dependence. AT1134965			

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification



**FTD-HT- 23-1202-72**

## **EDITED TRANSLATION**

**FTD-HT-23-1202-72**

**ELECTRIC CONDUCTIVITY OF A HIGH-DENSITY XENON  
PLASMA**

**By: S. I. Andreyev and V. Ye. Gavrilov**

**English pages: 5**

**Source: AN BSSR. Ordëna Trudovogo Krasnogo  
Znamenì Institut Fiziki. Voprosy  
Fiziki Nizkötëperaturnoy Plazmy,  
Izd-vo Nauka i Tekhnika, Minsk, 1970,  
p. 248-251.**

**Requester: ASD**

**Translated by: Henry Peck**

**Approved for public release;  
distribution unlimited.**

**THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.**

**PREPARED BY:**

**TRANSLATION DIVISION  
FOREIGN TECHNOLOGY DIVISION  
WP-AFB, OHIO.**

**- iii -**

**FTD-HT- 23-1202-72**

**Date 17 Nov 1972**

# U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	<i>А а</i>	A, a	Р р	<i>Р р</i>	R, r
Б б	<i>Б б</i>	B, b	С с	<i>С с</i>	S, s
В в	<i>В в</i>	V, v	Т т	<i>Т т</i>	T, t
Г г	<i>Г г</i>	G, g	У у	<i>У у</i>	U, u
Д д	<i>Д д</i>	D, d	Ф ф	<i>Ф ф</i>	F, f
Е е	<i>Е е</i>	Ye, ye; E, e*	Х х	<i>Х х</i>	Kh, kh
Ж ж	<i>Ж ж</i>	Zh, zh	Ц ц	<i>Ц ц</i>	Ts, ts
З з	<i>З з</i>	Z, z	Ч ч	<i>Ч ч</i>	Ch, ch
И и	<i>И и</i>	I, i	Ш ш	<i>Ш ш</i>	Sh, sh
Й й	<i>Й й</i>	Y, y	Щ щ	<i>Щ щ</i>	Shch, shch
К к	<i>К к</i>	K, k	Ъ ъ	<i>Ъ ъ</i>	"
Л л	<i>Л л</i>	L, l	Ы ы	<i>Ы ы</i>	Y, y
М м	<i>М м</i>	M, m	Ь ь	<i>Ь ь</i>	'
Н н	<i>Н н</i>	N, n	Э э	<i>Э э</i>	E, e
О о	<i>О о</i>	O, o	Ю ю	<i>Ю ю</i>	Yu, yu
П п	<i>П п</i>	P, p	Я я	<i>Я я</i>	Ya, ya

\* ye initially, after vowels, and after ъ, ы; e elsewhere.  
 When written as ѐ in Russian, transliterate as yě or è.  
 The use of diacritical marks is preferred, but such marks  
 may be omitted when expediency dictates.

## ELECTRIC CONDUCTIVITY OF A HIGH-DENSITY XENON PLASMA

S. I. Andreyev and V. Ye. Gavrilov

The purpose of this work is to experimentally investigate the dependence of specific electric conductivity ( $\sigma$ ) of xenon plasma on temperature (T) under conditions of the high concentration of charged particles when the concept of Debye screening is not used.

The measurements were made in quartz tubes with a diameter of  $d = 7.5, 10.5$ , and  $15.6$  mm at a distance of  $l = 150$  mm between electrodes. The temperature was determined from Planck's formula for the spectral density of the brightness of an absolutely black body  $b_{\lambda p}(T, \lambda)$ . Magnitude  $b_{\lambda p}(T, \lambda)$  was determined from the transport equation

$$b_{\lambda p} = \frac{b_{\lambda}}{1 - e^{-\tau_{\lambda}}}, \quad (1)$$

where  $e^{-\tau_{\lambda}}$  is the transparency of the plasma which was measured by illuminating the plasma with an independent source, and  $b_{\lambda}$  is the spectral density of the plasma brightness which was measured by comparison with a standard EV-39 type source [1]. The temperature values thus obtained with a variation in  $b_{\lambda}$  and  $e^{-\tau_{\lambda}}$  at different wavelengths coincided for the same discharge mode within the limits not exceeding  $300^{\circ}\text{K}$ .

The resistance of the plasma column ( $R$ ) was determined at the moment of the maximum current pulse ( $t_m$ ) from the equation

$$R = \frac{U_0 - \frac{1}{C} \int_0^{t_m} i(t) dt}{i_m}, \quad (2)$$

where  $U_0$  is the initial voltage to which capacitor  $C$  charges. Moment of time  $t_m$  was determined from the condition  $\left(\frac{di}{dt}\right)_{t=t_m} = 0$ . The oscillographic notation of the current  $i(t)$  was integrated and differentiated graphically. To increase the accuracy of the graphic integration and differentiation, the current oscillogram was increased to dimensions determined by the thickness of the oscillograph beam. The accuracy of the oscillographic notation  $i(t)$  obtained by a special shunt was monitored by methods described in work [2].

The resistance of the entire discharge circuit without a discharge envelope was measured in like manner and was subtracted from the values of  $R$  obtained in the presence of the discharge. The voltage between the electrodes of the discharge tube at moment  $t_m$  amounted to a magnitude on the order of a kilovolt (or several kilovolts), so that the electrode voltage drops were negligibly low.

To connect the electric conductivity of the plasma in the center of the discharge column with the plasma temperature at the same point the radial temperature distribution whose results we described earlier [3] were investigated. In accordance with this investigation the radial temperature distribution of plasma under our conditions is described by the equation

$$T(r) = 1,18 T_0 \left(0,5 - \frac{r}{d}\right)^{0,11}, \quad (3)$$

where  $T_0$  is the temperature on the axis of the plasma column of diameter  $d$ , and  $r > 0.25 d$ .



Measuring  $R$  and  $T$  under different discharge-current densities, we established the function between the values of  $\bar{\sigma}$  and  $\bar{T}$ , average in the cross section, in the first approximation. To calculate  $\sigma(T)$  in the second approximation, distribution (3) in the expression<sup>1</sup>

$$R = \frac{l}{2\pi \int_0^{d/2} \sigma[T(r)] r dr} \quad (4)$$

was calculated.

Hence there follows a subsequent connection between the experimentally measured values of  $R$  and  $\sigma_0$  in the center of the plasma column:

$$\sigma_0 = 1,08 \frac{l}{R \frac{\pi d^2}{4}} + 0,08 f(T_0) (\Omega \cdot \text{cm})^{-1}, \quad (5)$$

where  $f(T_0)$  takes values of 2, 4, 8, 20, and 45 when  $T_0$  is equal to 12, 14, 16, 18, and 20 thousand °K, respectively.

Since the experimental values under our conditions have an order of  $10^2 (\Omega \cdot \text{cm})^{-1}$ , the second term in expression (5) amounts to no more than 5% of the measured magnitude. The first term of this expression differs by 8% from the electric-conductivity value average over the cross section with a radial distribution of  $T(r)$  in terms of (3).

The experimental results  $\sigma_0(T_0)$  obtained on different-diameter tubes under various discharge modes but with the same temperature  $T_0$  proved to coincide within the limits of  $\pm 5\%$ . These results are shown in the figure. It also shows the results of calculating from

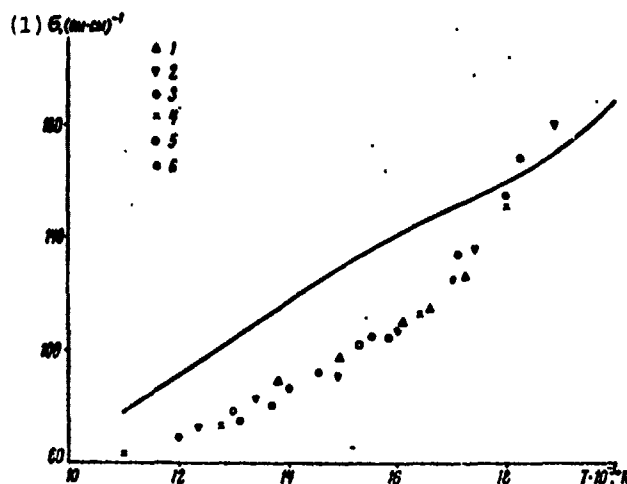
---

<sup>1</sup>It turned out that we can limit ourselves to the second approximation, since the third approximation differs from the second approximation within the accuracy limits of approximation (3).

the formula stemming from the approximation of paired collisions with the cutoff of the radius of motion of the Coulomb forces by the Debye radius [4]:

$$\sigma = 2,62 \cdot 10^{-4} T^{\frac{3}{2}} \frac{n_e}{\frac{n_1 \ln \Lambda_1}{\gamma_1} + \frac{4n_2 \ln \Lambda_2}{\gamma_2}}, \quad (6)$$

where  $\Lambda_{(1,2)} = \frac{3kT}{Z_{(1,2)} e^2} D$ ,  $D = \left( 6,9 \frac{T}{n_e + n_1 + 4n_2} \right)^{\frac{1}{2}}$  is the Debye radius,  $n_e$  is the electron concentration,  $n_1$  are the one-time ionized atoms,  $n_2$  are twice ionized atoms, and  $\gamma_1 = 0.582$  and  $\gamma_2 = 0.683$  are factors which consider the interelectrode impact.



Temperature function of the specific electrical conductivity of xenon plasma: 1 - points relate to the case of a discharge in a tube with an internal diameter of  $d = 15.5$  mm filled with xenon when  $p_0 = 400$  mm Hg; 2 -  $d = 10.5$  mm,  $p_0 = 200$  mm Hg; 3 -  $d = 10.5$  mm,  $p_0 = 400$  mm Hg; 4 -  $d = 10.5$  mm,  $p_0 = 600$  mm Hg; 5 -  $d = 7.4$  mm,  $p_0 = 400$  mm Hg; 6 -  $d = 10.5$  mm,  $p_0 = 400$  mm Hg. The discharge mode: points 1-5 -  $C = 415$   $\mu$ F;  $L = 25$   $\mu$ H; 6 -  $C = 4.8$   $\mu$ F;  $L = 1$   $\mu$ H. The discharge-column length in all cases amounted to 150 mm.  
KEY: (1)  $\sigma(\Omega \cdot \text{cm})^{-1}$ .

It should be noted that the qualitatively excellent function  $\sigma(T)$  calculated from (6) is observed. The numerical agreement of

the calculation results from (6) with the experiment is obviously random, since the concept of Debye screening, based on a statistical averaging of a large number of particles in the Debye sphere, has no physical sense.

Actually, as the data shown in the table indicates, the number of particles in the sphere of the Debye radius ( $N$ ) proves to be less than unity under the conditions of our experiment. The magnitude of the Debye radius ( $D$ ) is less than the average distance between particles ( $n_e^{-1/3}$ ). The average energy of the Coulomb interaction  $e^2(n_e+n_i)^{-1/3}$  is approximately 5 times less than the thermal value of ( $kT$ ). The consideration of the role of the twice-ionized atoms leads to a reduction in the calculation values of  $\sigma$  in the region of 18-20 thousand °K. In calculating the ionized composition of plasma the radial temperature distribution and the reduction in the ionized potential according to work [5] were considered. Let us note that if we assume the digital factor in the expression for  $\Lambda_z$  to be equal to 2 [6], and not 3 [4], the calculation value of  $\sigma$  is approximately twice as high as the experimental value in the region of 12-14 thousand °K.

Table. Data for calculative  $\sigma(T)$ .

$T \cdot 10^{-4}, ^\circ K$	$n_e \cdot 10^{-19}, \text{cm}^{-3}$	$D \cdot 10^3, \text{cm}$	$\frac{1}{n_e^{1/3}} \cdot 10^3, \text{cm}$	$N = \frac{4}{3\pi D^3} n_e$	$\frac{(n_e + n_i)^{1/2}}{kT}$	$\ln \Lambda_z$
12	1,6	4,3	7,9	0,5	0,22	2,21
14	2,9	3,4	7,0	0,5	0,21	2,15
16	4,0	3,1	6,3	0,5	0,21	2,18
18	4,7	3,0	6,0	0,5	0,20	2,27
20	5,8	2,9	5,6	0,6	0,18	2,26

#### Bibliography

1. Огурцова Н. Н., Подмошенский И. В. Опт. и спектр., 4, 539, 1958.
2. Андреев С. И. ПТЭ, 4, 87, 1961.
3. Андреев С. И., Гаврилов В. Е. Опт. и спектр., 25, 125, 1969.
4. Спайтер Л. Физика полностью ионизованного газа. М., «Мир», 1965.
5. Ecker G., Weizel W. Z. Naturforschung, 12a, 51b, 859, 1957; 13a, 1093, 1958.
6. Гинзбург В. Л. Распространение электромагнитных волн в плазме. М., «Наука», 1967.